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COAL-MINE EXPLOSIONS AND COAL- AND METAL-MINE FIRES IN THE UNITED STATES DURING THE FISCAL YEAR ENDED JUNE 30, 1944

BY

D. HARRINGTON AND W. J. FENE

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COAL-MINE EXPLOSIONS AND COAL- AND METAL-MINE FIRES IN THE UNITED STATES DURING THE FISCAL YEAR ENDED JUNE 30, 1944[1]

By D. Harrington[2] and W. J. Fene[3]

INTRODUCTION

Although the explosion-fatality record for the fiscal year 1944 showed considerable improvement over those of the preceding 4 years, it is still far from creditable, and the coal-mining industry and agencies interested in the prevention of coal-mine accidents should not be satisfied until accidents from explosions and fires are eliminated. In view of present knowledge of the methods of preventing explosions and fires, such disasters are inexcusable and discredit the mining industry. Despite this knowledge, far too many coal-mine operators and employees continue to follow procedures that have resulted in disasters in the past. Included in the appendix to this circular are a number of safety measures designed to prevent coal-mine explosions and fires and metal-mine fires. Their adoption is essential if explosions and fires are to be prevented, as certainly they should be.

An epidemic of disastrous mine fires of electrical origin during the past 2 years emphasizes the need for better methods of protection of underground electrical circuits. At present, committees of mining-electrical engineers, electrical-equipment manufacturers' representatives, and others are cooperating with the Bureau of Mines in seeking means to solve this problem.

During the fiscal year 1944, 23 explosions in coal mines resulted in 94 fatalities, compared with an average of 24 explosions and 168 fatalities per year during the preceding 4 years. Thirty-two underground coal-mine fires during the year resulted in 8 fatalities, compared with an average of 24 fires and 10 fatalities during each of the preceding 4 years.

SUMMARY OF MINE EXPLOSIONS, BY STATES AND CAUSES

Table 1 summarizes essential data on 23 coal-mine explosions known to have occurred in 8 States and Alaska and to have resulted in 94 deaths during the fiscal year ended June 30, 1944. The table contains information on all

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coal-mine explosions in the United States during the fiscal year that were brought to the attention of the Bureau of Mines and is believed to cover every explosion in which life was lost or considerable damage was done. These were 9 fewer than were known to have occurred in the previous year; the number of deaths (94) was 58 fewer than in 1943.

The greatest number of deaths (29) from explosions in any State during the fiscal year 1944 occurred in Alabama. West Virginia had 28 deaths from this cause, Pennsylvania 15, Kentucky 14, Arkansas 6, and Colorado and Tennessee, 1 each. An explosion occurring in Alaska and one in Oklahoma did not result in death.

The 5 major explosions during the fiscal year resulted in 81 deaths; in 1943 there were 5 major explosions with 122 deaths; and during 1942 there were 7 major explosions with 135 deaths. (A major explosion is one in which five or more fatalities occur.) Ten of the 23 explosions known to have occurred during the past year did not result in fatalities. The anthracite mines of Pennsylvania experienced their first major explosion in 6 years, and Pennsylvania bituminous mines had only one fatality from explosions during the fiscal year 1944.

Table 2 summarizes the causes of explosions that occurred during the fiscal years 1929 to 1944, as determined from records of the Health and Safety Branch of the Bureau of Mines. It is shown that 59 persons were killed during the fiscal year 1944 in explosions initiated by electricity, compared with 66 in the previous year and an average of 68.8 per year for the preceding 15 years. During the fiscal year 1944, Pennsylvania had 4 explosions caused by electricity with 15 deaths; Alabama had 3 such explosions, with 29 deaths; West Virginia, 2 with 12 deaths; and Arkansas, 2 with 3 deaths.

During the fiscal year 1944, 6 mine explosions were caused by open lights or smoking, compared with 9 such explosions in the previous year and with an average of 8.7 during the previous 15 years. Five deaths resulted from explosions caused by open lights or smoking during 1944, compared with 86 from this cause in 1943 and an average of 26.2 during the previous 15 years. Arkansas had 2 explosions with 3 deaths caused by open lights or smoking; Pennsylvania had 2 explosions with no deaths; Kentucky 1 with 2 deaths; and Oklahoma 1 with no deaths. In three of these explosions, gas was ignited by carbide lamps; in two, gas was ignited when miners attempted to smoke; and in one, gas was ignited while attempting to light a fuse with a match.

Three explosions resulting in one death were caused by explosives during the fiscal year 1944, compared with three such explosions during the previous year and to an average of 3.6 explosions and 21.2 deaths during the previous 15 years.

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TABLE 1. -- Summary of coal-mine explosions, by States and causes, fiscal year ended June 30, 1944

State	Lighting used			Fatalities, by ignition causes									
				Electricity		Open lights or smoking		Explosives		Miscellaneous		Total	
	Open	Closed	Unknown	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions
Alabama	-	3	-	29	3	-	-	-	-	-	-	29	3
Alaska	-	-	1	-	-	-	-	-	1	-	-	-	1
Arkansas	4	-	-	3	2	3	2	-	-	-	-	6	4
Colorado	1	-	1	-	-	-	-	1	2	-	-	1	2
Kentucky	1	1	-	-	-	2	1	-	-	12	1	14	2
Oklahoma	-	-	1	-	-	-	1	-	-	-	-	-	1
Pennsylvania .	-	5	1	15	4	-	2	-	-	-	-	15	6
Tennessee.....	-	-	1	-	-	-	-	-	-	1	1	1	1
West Virginia	-	3	-	12	2	-	-	-	-	16	1	28	3
Total	6	12	5	59	11	5	6	1	3	29	3	94	23

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TABLE 2.-- Summary of data on explosions, by causes, fiscal years 1929-44, inclusive

Year	Lighting used			Fatalities, by ignition causes									
				Electricity		Open lights or smoking		Explosives		Miscellaneous or unknown		Total	
	Open	Closed	Unknown	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions
1929	18	19	1	93	18	14	11	26	8	6	1	139	38
1930	8	25	1	154	18	21	8	24	6	-	2	199	34
1931	12	14	-	143	9	56	11	18	6	-	-	217	26
1932	15	14	4	11	10	33	15	42	5	1	3	87	33
1933	7	14	1	25	8	63	8	29	4	5	2	122	22
1934	9	14	3	21	10	2	9	2	3	3	4	28	26
1935	5	16	-	29	10	6	8	3	2	16	2	54	22
1936	15	9	1	20	5	10	17	4	1	4	2	38	25
1937	4	12	4	53	12	3	5	-	1	6	2	62	20
1938	10	16	3	24	10	77	11	61	6	8	2	170	29
1939	2	12	-	13	9	2	3	-	-	1	2	16	14
1940	6	11	1	99	6	2	5	103	5	2	2	206	18
1941	5	21	-	145	14	15	9	3	3	-	-	163	26
1942	5	17	-	133	14	3	2	2	2	14	4	152	22
1943	11	17	4	66	19	86	9	-	3	-	1	152	32
1944	6	12	5	59	11	5	6	1	3	29	3	94	23
Total	138	243	28	1088	183	398	137	318	58	95	32	1899	410

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Three explosions occurring during the fiscal year are listed under miscellaneous causes. Two of these explosions, which resulted in 13 deaths, occurred when officials attempted to relight flame safety lamps with matches in the presence of gas. One very violent explosion occurred in West Virginia and killed 16 men who were attempting to extinguish a mine fire. In an Alabama mine, a second explosion, caused by fire ignited by a first explosion, killed 10 men of a rescue crew; the fatalities in the Alabama explosion, however, are charged to electricity, because the first explosion was caused by an electric arc.

Table 3 shows the record of explosions by States for the past 16 fiscal years. During this 16-year period, 410 mine explosions caused 1,899 deaths, an average of 25.62 explosions and 118.62 deaths per year and an average of 4.63 fatalities per explosion. The number of explosions (23) occurring during the fiscal year 1944 and the resulting number of deaths were somewhat less than the average for the preceding 15 years. For the 16-year period, Pennsylvania had the greatest number of explosions--108, with 317 deaths. West Virginia had 71 explosions with 381 deaths; Ohio, with only 16 explosions, had 209 deaths. It is encouraging to note that during the 16-year period, Kansas and Maryland had only one explosion each, two fatalities occurring in Kansas and one in Maryland. New Mexico has not had an explosion during the past 11 years. Utah has had only one explosion, with one death during the past 14 years; Wyoming has had only two known explosions, with a total of eight deaths during the 16-year period; and Montana experienced its first major explosion during 1943.

The average number of deaths per explosion during the past 16 years has been 4.63, with a range for States of 1.00 for Maryland to 74.0 for Montana. States with the highest averages are Montana, 74.0 (1 explosion); Ohio, 13.06; Virginia 8.07; and Oklahoma 7.10. The following coal-producing States are not listed in table 3, as they are not known to have had an explosion during the past 16 years: Iowa, Michigan, Missouri, North Dakota, and Texas.

CAUSES OF EXPLOSIONS

Table 4 gives data on causes of explosions in the United States during the past 16 years as reported to the Bureau of Mines. In all, 410 explosions were studied during that period, an average of 25.6 per year. There were 23 explosions during the fiscal year 1944, or 9 fewer than during the previous year and nearly 3 fewer than the average of the preceding 15 years.

Table 4 shows that electricity was responsible for 183 (44.7 percent) and open lights and smoking for 137 (33.4 percent) of the explosions recorded during the 16 years; hence, 78.1 percent of all known explosions occurring during this 16-year period were started by ignitions due to electricity, open lights, and smoking. This situation definitely indicates that effective precautions are not being taken as to these hazards.

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TABLE 3. -- Record of explosions, by States, during fiscal years 1929-44, inclusive

	1929		1930		1931		1932		1933		1934		1935		1936		1937		1938		1939		1940		1941		1942		1943		1944		Total, 16 years		Average per year		Average deaths per ignition
	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	
Alabama.....	13	7	8	4	-	2	4	5	-	-	2	2	-	1	-	1	-	-	37	2	-	1	1	4	6	5	11	1	12	3	29	3	123	41	7.69	2.56	3.00
Alaska.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	1	-	-	-	-	-	-	-	-	-	-	0	1	14	2	.87	.12	7.00
Arkansas.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	1	4	4	-	-	3	1	10	1	8	2	5	4	6	4	41	17	2.56	1.06	2.41
Colorado.....	-	-	-	1	-	-	4	3	1	1	-	-	-	-	12	2	1	1	-	-	-	-	1	1	2	1	34	2	3	1	1	2	59	15	3.69	.94	3.93
Illinois.....	-	3	10	2	2	1	3	3	54	1	-	-	-	-	-	-	-	-	5	2	1	1	1	1	-	1	8	1	1	2	-	-	85	18	5.31	1.12	4.72
Indiana.....	-	-	-	-	28	1	-	-	4	2	-	-	-	-	2	3	-	-	22	2	-	-	-	-	16	3	-	-	-	1	-	-	72	12	4.50	.75	6.00
Kansas.....	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	.13	.06	2.00
Kentucky.....	11	3	16	1	-	-	3	1	26	2	-	1	1	1	9	1	-	-	-	2	1	1	28	1	-	-	16	2	10	4	14	2	135	22	8.44	1.37	6.15
Maryland.....	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	.06	.06	1.00
Montana.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	74	1	-	-	74	1	4.62	.06	74.00
New Mexico....	-	-	-	-	8	3	-	-	14	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	4	1.37	.25	5.50
Ohio.....	3	3	1	2	88	3	-	-	-	-	-	-	-	-	4	1	-	-	2	1	-	-	72	1	32	2	-	-	7	3	-	-	209	16	13.06	1.00	13.06
Oklahoma.....	1	1	71	4	45	2	-	-	3	2	-	-	3	2	-	-	3	1	-	-	1	1	2	1	1	1	5	2	7	3	0	1	142	21	8.87	1.31	7.10
Pennsylvania..	70	9	16	8	23	7	7	6	9	6	16	14	24	11	8	10	14	5	30	7	3	1	-	2	76	5	5	5	1	4	15	6	317	108	19.81	6.75	2.93
Tennessee.....	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1	1	2	-	2	10	1	1	1	13	11	.81	.69	1.20
Utah.....	1	2	30	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	32	6	2.00	.37	5.33
Virginia.....	2	1	-	-	-	-	54	3	-	-	2	3	18	2	-	-	2	1	46	3	4	1	1	1	-	-	-	-	-	1	-	-	129	16	8.06	1.00	8.07
Washington....	-	-	17	2	-	2	-	-	2	1	-	2	-	-	-	4	1	2	-	1	-	2	1	2	-	-	-	1	-	1	-	-	21	19	1.31	1.19	1.10
West Virginia.	36	7	23	5	11	4	11	7	9	5	8	4	5	4	3	3	36	8	5	3	6	4	95	2	18	4	65	4	22	4	28	3	381	71	23.81	4.44	5.36
Wyoming.....	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-	-	-	-	5	1	-	-	-	-	-	-	-	-	-	-	-	-	8	2	.50	.12	4.00
Total	139	38	199	34	217	26	87	33	122	22	28	26	54	22	38	25	62	20	170	29	16	14	206	18	163	26	152	22	152	32	94	23	1899	410	118.62	25.62	4.63

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TABLE 4. -- Comparison of explosions by ignition causes, fiscal years 1929-44, inclusive

Year	Ignition by electricity		Ignition by open lights or smoking		Ignition by explosives		Ignition due to unknown or miscellaneous causes		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1929	18	47.4	11	29.0	8	21.0	1	2.6	38	100
1930	18	52.9	8	23.5	6	17.6	2	6.0	34	100
1931	9	34.6	11	42.3	6	23.1	-	-	26	100
1932	10	30.3	15	45.5	5	15.1	3	9.1	33	100
1933	8	36.4	8	36.4	4	18.1	2	9.1	22	100
1934	10	38.5	9	34.6	3	11.5	4	15.4	26	100
1935	10	45.4	8	36.4	2	9.1	2	9.1	22	100
1936	5	20.0	17	68.0	1	4.0	2	8.0	25	100
1937	12	60.0	5	25.0	1	5.0	2	10.0	20	100
1938	10	34.5	11	37.9	6	20.7	2	6.9	29	100
1939	9	64.3	3	21.4	-	-	2	14.3	14	100
1940	6	33.3	5	27.8	5	27.8	2	11.1	18	100
1941	14	53.8	9	34.6	3	11.6	-	-	26	100
1942	14	63.6	2	9.1	2	9.1	4	18.2	22	100
1943	19	59.4	9	28.1	3	9.4	1	3.1	32	100
1944	11	47.8	6	26.1	3	13.05	3	13.05	23	100
Total	183	44.7	137	33.4	58	14.1	32	7.8	410	100
Average	11.4	44.7	8.6	33.4	3.6	14.1	2.0	7.8	25.6	100

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The number of explosions of electrical origin during the past year (11) about equals the average for the preceding 15 years (11.4). The number of explosions caused by open lights and smoking (6) is about 31 percent less than the average (8.7) from these causes for the preceding 15 years.

Table 4 shows that 3 explosions were caused by explosives during the past year, compared with the same number the previous year and an average of 1.9 for the preceding 15 years.

Three explosions are listed under unknown or miscellaneous causes.

EXPLOSION FATALITIES, BY CAUSES

Table 5 compares explosion fatalities by causes and shows that during the past 16 years, 1,899 fatalities resulted from mine explosions in the United States, an average of 118.7 a year. The explosion fatalities (94) during the fiscal year 1944 are 58 fewer than during the previous year (152) and well below (21.5 percent) the average for the preceding 15-year period (120). Five major explosions during the year resulted in 81 deaths, and 18 minor explosions caused 13 deaths, as compared with the record for the fiscal year 1943, when 5 major explosions with 122 deaths and 27 minor explosions with 30 deaths occurred.

Explosions of electrical origin were responsible for 59 (62.8 percent) deaths during the fiscal year 1944; this represents a small decrease over the 66 deaths from this cause during 1943 and is less than the average of 68.6 deaths for the preceding 15 years. The decrease in the number of explosions and the number of deaths from explosions of electrical origin during the past year is gratifying; however, constant vigilance is necessary if the existing unfavorable conditions brought about by the much greater use of electricity in coal mines because of the war are to be overcome.

Open lights and smoking resulted in 5 deaths, or 5.3 percent of the fatalities due to explosions during the fiscal year 1944, compared with 86 deaths (56.6 percent) for the previous year and an average of 26.2 deaths from this cause during the preceding 15 years. Two explosions resulting in 4 deaths were caused by smoking, 1 explosion resulting in 1 death by an open carbide light, and 2 explosions caused by carbide lights did not result in fatalities. Every man who works in a coal mine is, or at least should be, aware of the dangers of open lights and smoking; despite this knowledge, however, explosions caused by the use of open lights and from smoking continue to occur year after year. The type of lighting used at a mine is primarily the responsibility of the operator; however, in several instances attempts to install closed lights have been resisted by the miners, notwithstanding the fact that the use of open lights in mines is both unsafe and inefficient and, in addition, has caused the death of hundreds of mine worker Prohibition of smoking underground is the responsibility of both the operator and the miner. It is the operator's responsibility to establish no-smoking rules and to endeavor to see that they are enforced; it is the responsibility of the miner to refrain from smoking while underground and to see that his fellow miners do likewise.

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TABLE 5. -- Comparison of explosion fatalities, by causes of ignition, fiscal years 1929-44, inclusive

Year	Ignition by electricity		Ignition by open lights or smoking		Ignition by explosives		Ignition due to unknown or miscellaneous causes		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1929	93	66.9	14	10.1	26	18.7	6	4.3	139	100
1930	154	77.4	21	10.5	24	12.1	-	-	199	100
1931	143	65.9	56	25.8	18	8.3	-	-	217	100
1932	11	12.7	33	37.9	42	48.3	1	1.1	87	100
1933	25	20.5	63	51.6	29	23.8	5	4.1	122	100
1934	21	75.0	2	7.1	2	7.1	3	10.8	28	100
1935	29	53.7	6	11.1	3	5.6	16	29.6	54	100
1936	20	52.6	10	26.4	4	10.5	4	10.5	38	100
1937	53	85.5	3	4.8	-	-	6	9.7	62	100
1938	24	14.1	77	45.3	61	35.9	8	4.7	170	100
1939	13	81.3	2	12.5	-	-	1	6.2	16	100
1940	99	48.3	2	1.0	103	49.7	2	1.0	206	100
1941	145	89.0	15	9.1	3	1.9	-	-	163	100
1942	133	87.5	3	2.0	2	1.3	14	9.2	152	100
1943	66	43.4	86	56.6	-	-	-	-	152	100
1944	59	62.8	5	5.3	1	1.1	29	30.8	94	100
Total	1088	57.3	398	21.0	318	16.7	95	5.0	1899	100
Average	68.0	57.3	24.9	21.0	19.9	16.7	5.9	5.0	118.7	100

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During the past 16 years, 318 (16.7 percent) of all deaths due to explosions resulted from explosions caused by explosives. During the fiscal year 1944, 3 explosions and 1 death resulted from this cause, compared with 3 explosions and no deaths during the previous year and an average of 21.1 deaths for the preceding 15 years.

CAUSES OF EXPLOSIONS STARTED BY ELECTRICITY

Table 6 gives data available to the Bureau of Mines on causes of explosions of electrical origin in the United States for the fiscal years 1929-44. During this period there are known to have been 183 explosions of electrical origin, of which 11, with 59 deaths, occurred during the fiscal year 1944.

Trolley or cable-reel locomotives and nonpermissible mining machines jointly were responsible for 46.4 percent of the explosions of electrical origin during the 16-year period and for 72.7 percent during the past year.

During the past year, trolley or cable-reel locomotives were responsible for five explosions, nonpermissible mining machines for three, and nonpermissible electric drill, nonpermissible electric motor, and electric arc for one each.

Most coal-mine explosions of electrical origin during the past 16 years have shown evidence of carelessness of various kinds, including (1) failure to test for gas before taking electrical equipment into working places, or failure to test from time to time while using this equipment; (2) use of electrical equipment too soon after the mine fan has been started after a shut-down; (3) failure to examine a mine properly on idle days when only a skeleton crew is in the mine; (4) use of haulageways as return airways, a practice that is always hazardous whether in gassy or nongassy mine; (5) failure to install and utilize permissible electrical equipment or to maintain permissible equipment in a safe or permissible condition; (6) haphazard methods of splicing cable and in attaching cable nips to power wires; and other careless practices, many of them directly involving ventilation.

Conditions brought about by the war, such as difficulty in obtaining machinery replacement parts and a shortage of skilled labor, are likely to result in increasing numbers of explosions of electrical origin unless every precaution is taken to prevent them; in fact 1941, 1942, 1943, and 1944 actually do show more explosions of electrical origin.

COMPARISON OF LIGHTING IN MINES WHERE EXPLOSIONS OCCURRED

Table 7 indicates the method of lighting used in mines where explosions occurred during the past 16 years. Of the 410 explosions that occurred, 138 (33.7 percent) were in open-light mines, 244 (59.5 percent) in closed-light mines, and 28 (6.8 percent) in mines in which lighting practice is unknown. During the fiscal year 1944, 6 (26.1 percent) of the explosions occurred in open-light mines, compared with an average of 8.8 explosions per year in open-light mines during the preceding 15 years.

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TABLE 6 — Electrical causes of explosions, fiscal years 1929-44, inclusive

Type of equipment	Explosions of electrical origin, by fiscal years																Total, 16 years	Number killed	
	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944		1943	1944
Trolley or cable-reel locomotive 1/	5	5	1	1	4	5	3	1	5	4	3	-	3	1	-	5	45	-	14
Nonpermissible mining machine 2/	5	5	3	3	1	-	2	1	3	3	-	2	4	2	4	3	40	20	3
Nonpermissible electric motor	4	3	-	-	-	-	2	-	-	1	2	-	1	-	2	1	16	-	14
Nonpermissible shot-firing battery or circuit	-	3/2	3/3	1	-	1	-	-	-	-	-	-	-	-	-	-	2	-	-
Cable nips or blown-out cable	-	2	-	-	-	1	-	-	1	-	1	-	1	-	1	-	7	-	-
Nonpermissible electric drill	-	-	-	2	-	1	2	-	-	-	2	2	3	1	5	1	19	8	-
Nonpermissible storage-battery locomotive	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-
Nonpermissible electric hoist	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Faulty wiring	2	2	-	-	-	-	-	1	1	-	-	-	-	-	-	-	6	-	-
Trolley wire	1	-	2	1	-	-	-	1	-	-	-	-	1	2	-	-	8	-	-
Electric arc	2	-	1	2	1	2	1	4/1	1	2	1	2	1	8	7	1	33	38	28
Signal wire	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	2	-	-
Total	18	18	9	10	8	10	10	5	12	10	9	6	14	14	19	11	183	66	59

1/ One not included in total; may have been from open light.
2/ One not included in total; may have been from smoking.
3/ Not included in total; may have been from overcharged shot.
4/ Included, but may have been from smoking.

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TABLE 7. -- Summary of lighting in mines where explosions occurred, fiscal years 1929-44, inclusive

Year	Open lights		Closed lights		Lighting unknown		Total	
	Explosions	Percent	Explosions	Percent	Explosions	Percent	Explosions	Percent
1929	18	47.4	19	50.0	1	2.6	38	100
1930	8	23.5	25	73.5	1	3.0	34	100
1931	12	46.2	14	53.8	-	-	26	100
1932	15	45.5	14	42.4	4	12.1	33	100
1933	7	31.8	14	63.6	1	4.6	22	100
1934	9	34.6	14	53.9	3	11.5	26	100
1935	5	26.1	17	73.9	-	-	22	100
1936	15	60.0	9	36.0	1	4.0	25	100
1937	4	20.0	12	60.0	4	20.0	20	100
1938	10	34.5	16	55.2	3	10.3	29	100
1939	2	14.3	12	85.7	-	-	14	100
1940	6	33.3	11	61.1	1	5.6	18	100
1941	5	19.2	21	80.8	-	-	26	100
1942	5	22.7	17	77.3	-	-	22	100
1943	11	34.4	17	53.1	4	12.5	32	100
1944	6	26.1	12	52.2	5	26.1	23	100
Total	138	33.7	244	59.5	28	6.8	410	100

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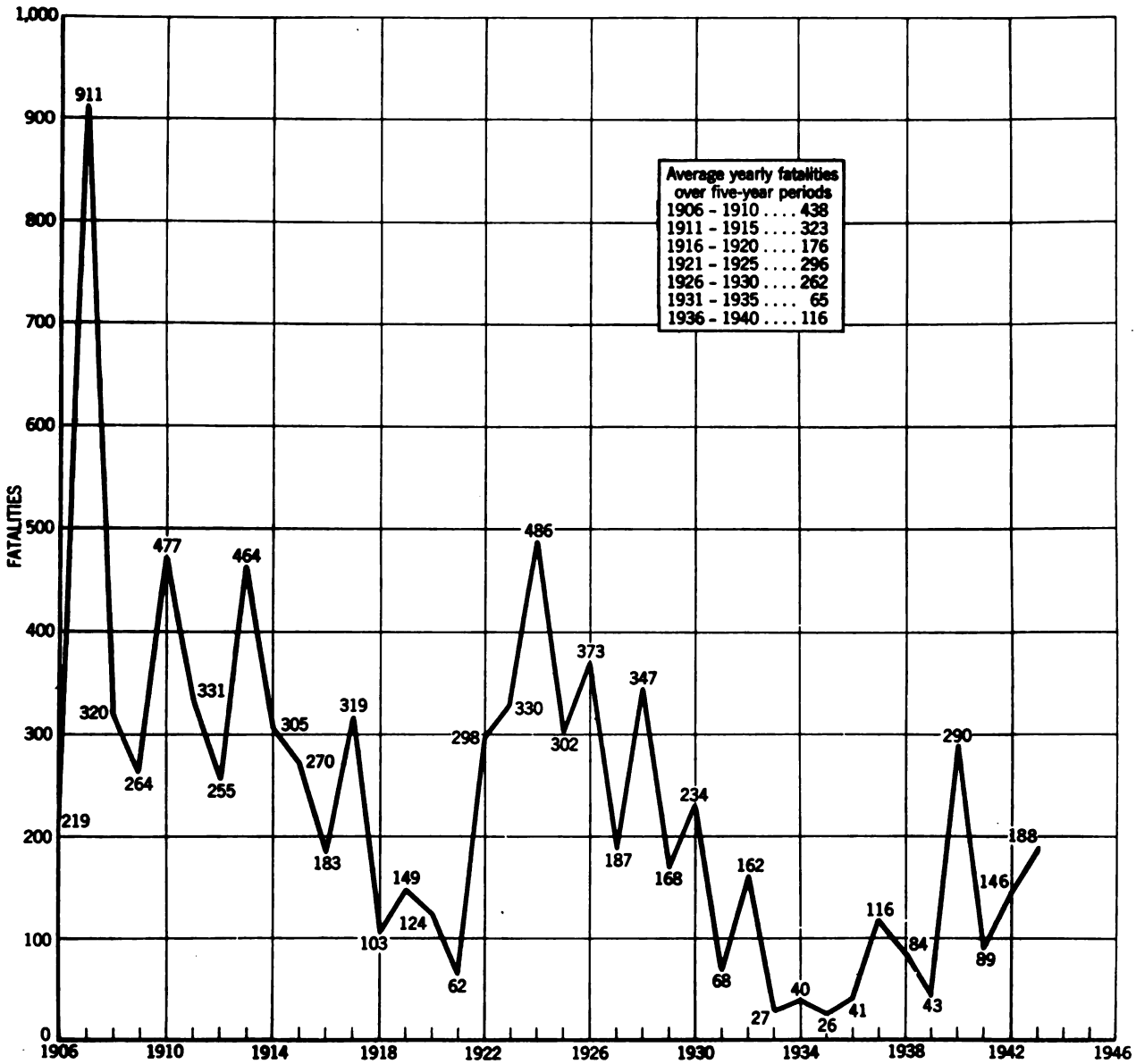

FIGURE 1.- Fatalities from gas and coal-dust explosions in bituminous-coal mines.

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During the fiscal year 1944, 52.2 percent of the explosions occurred in closed-light mines, and during the past 16 years 59.5 percent of all explosions occurred in mines using closed lights. This may be interpreted in several ways. Probably the most nearly correct explanation is that in many States the most gassy, hence the most dangerous, mines now use closed lights. No explosion is known ever to have been caused by an electric cap lamp; this indicates that almost unquestionably there has been carelessness in other explosion-prevention practices in some closed-light mines, otherwise more than half of the coal-mine explosions in recent years would not have occurred in closed-light mines. In many mines that have adopted closed lights, too much dependence is placed on the lamps, with the result that ventilation and other precautionary measures are neglected. Among the bad practices followed in mines or parts of mines known to give off explosive gas and placed on a closed-light basis is the use of open-type electrical equipment (pumps, drills, cutting machines, loading machines, conveyor motors, etc.), a flagrant violation of sane mining practice that is absolutely unnecessary and inexcusable. Many explosions in both open- and closed-light mines are due to conditions brought about by the use of fan-tubing systems of ventilation. Moreover, smoking is practiced in many closed-light mines, sometimes with the consent of the management but more frequently through violation of company rules or State laws or regulations. Use of the up-to-date permissible electric cap lamps is unquestionably one of the most effective means now known of promoting safety in mining (coal or metal), and any individual or agency failing to use or trying to prevent the use of electric cap lamps in mines is woefully ignorant of mine safety requirements or is deliberately indifferent to the operation of mines on anything approaching an efficient or a humanitarian basis. On the other hand, any neglect of other essential safety procedures through placing undue reliance on electric cap lamps is bound to result in disaster sooner or later; such neglect carries with it a responsibility analogous to such violation of law as smoking in closed-light mines.

EXPLOSIONS IN BITUMINOUS-COAL MINES

Figure 1 shows the trend of fatalities resulting from gas and dust explosions in bituminous-coal mines of the United States during the calendar years 1906 to 1943, inclusive. The trend of explosion fatalities was downward from 1907 to 1921, with a marked rise from 1922 to 1924, and a definite, relatively steady decline from 1924 to 1935; however, the trend has been upward during the past 7 years, especially in 1937, 1938, 1940, 1941, 1942, and 1943. It is significant that in every alternate year from 1924 to 1936, the number of deaths has increased over that of the preceding year, although the general trend has been downward. A plausible explanation is that a year with a relatively low explosion-fatality record causes relaxation in efforts to prevent accidents (or at least in prevention of explosions) during the following year; conversely, a year with a high explosion-fatality record causes additional precautionary measures to be taken. The tabulation on the graph of average annual fatalities from bituminous-coal-mine explosions for 5-year periods from 1906-10 to 1936-40 is illuminating, as it shows a large and fairly steady decrease in annual fatalities from 438 for the 5-year period 1906-10 to 65 for the 5-year period 1931-35, a drop of 85.5 percent;

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however, it is also shown that during the most recent 5-year period, 1936-40, there has been an increase of more than 78 percent in explosion fatalities, as compared with the previous 5-year period, 1931-35. The record for 1931-35 bolstered hopes that disastrous mine explosions in the United States were a thing of the past, but the record of the past 4 years has shattered them. The explosion record for the past 4 years should cause the coal-mining industry grave concern. Several factors contribute to this bad record, such as (1) the rapid increase in the use of electrical equipment at face regions, where gas and dust are most likely to be found; (2) the increased demand for coal to supply war requirements; (3) desire of mine operators to obtain maximum tonnage per machine at minimum cost, which has resulted in neglect of rudimentary precautionary measures; (4) multiple-shift operation, which does not allow time for adequate maintenance of equipment, effective rock dusting, and testing for gas by fire-bosses; (5) decrease in supervision owing to demands on supervisors for maximum tonnage and loss of competent supervisors to the armed forces and the more highly paid war industries; (6) lack of effective supervision owing to numerous causes; (7) inability to obtain adequate equipment repair and replacement parts; (8) shortage of labor, especially skilled labor; (9) failure of both miners and mining officials to show regard for safety in changing from hand-loading to mechanized methods; (10) the necessity to utilize over-age workers; and (11) fatigue of both workers and supervisors due to overwork.

In view of the experience of the past 2 years, and considering the fact that the demand for coal probably will increase greatly during the coming year, the outlook is not at all bright if the same unsafe methods and procedures are to be continued in effect or are to be accentuated by increased demands for coal with decreases in the facility to secure it.

MINE FIRES

During the fiscal year 1944, 32 coal-mine fires, which resulted in the death of 8 men, were called to the attention of the Bureau. Table 8 shows that 7 of these fires were reported in Pennsylvania, 5 in Illinois, 3 each in Colorado, Utah, Washington, and West Virginia, 2 each in Alabama, Kentucky, and Ohio, and 1 each in Texas and Wyoming. These were 11 more than occurred during the preceding year and 14 more than the average for the preceding 14 years. The 8 fatalities from fires were 7 fewer than in the preceding year and equalled the average for the preceding 14 years. Twenty-five surface fires, 17 of which were at metal mines, occurred during the fiscal year 1944; these are not indicated in table 8. An explosion that killed 16 men resulted from one of the coal-mine fires, and although these fatalities are charged to explosions, they indirectly resulted from the fire. Following a mine fire caused by a trolley wire, 18 men were rescued after having been barricaded for 14 hours.

Of the 32 fires that occurred during the fiscal year 1944, 12 were of electrical origin, 3 resulted from the use of nonpermissible explosives, and 17 were of miscellaneous or unknown origin. During the past 15 years, 356 fires have been reported, 112 of which (31.4 percent) were of electrical origin. Electric trolley wires were involved in 7 of these.

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TABLE 8. -- Summary of mine fires, by States, fiscal years 1944 and 1930-31, inclusive

State	Lighting used			Fatalities, by cause of ignition									
				Electricity		Open lights		Explosives		Unknown or miscellaneous		Total	
	Open	Closed	Unknown	Deaths	Fires	Deaths	Fires	Deaths	Fires	Deaths	Fires	Deaths	Fires
Alabama	-	-	2	-	1	-	-	-	-	-	1	-	2
Colorado	-	1	2	-	-	-	-	-	-	-	3	-	3
Illinois	1	-	4	-	-	-	-	-	2	-	3	-	5
Kentucky	-	-	2	-	1/1	-	-	-	1	-	-	-	1/2
Ohio	-	2	-	-	2	-	-	-	-	-	-	-	2
Pennsylvania .	1	3	3	6	5	-	-	-	-	-	2	6	7
Texas	-	-	1	-	-	-	-	-	-	-	1	-	1
Utah	-	2	1	-	-	-	-	-	-	2	3	2	3
Washington ...	-	-	3	-	-	-	-	-	-	-	3	-	3
West Virginia	-	2	1	-	3	-	-	-	-	-	-	-	3
Wyoming	-	-	1	-	-	-	-	-	-	-	1	-	1
Total 1944	2	10	20	6	12	-	-	-	3	2	17	8	32
1943	8	7	12	13	6	-	-	-	1	2	20	15	27
1942	10	7	9	4	9	-	2	-	1	17	14	21	26
1941	3	8	5	2	7	-	-	-	3	-	6	2	16
1940	12	9	6	2	5	-	2	-	1	-	19	2	27
1939	9	9	2	1	8	-	1	-	3	2	8	3	20
1938	7	6	11	1	7	2	2	-	1	5	14	8	24
1937	7	4	10	9	5	-	-	-	3	2	13	11	21
1936	16	4	3	1	7	-	2	-	3	3	11	4	23
1935	7	5	14	11	11	-	1	-	-	-	14	11	26
1934	10	5	3	-	4	-	-	5	5	1	9	6	18
1933	12	6	9	-	7	-	-	-	2	2	18	2	27
1932	8	5	8	1	8	-	-	-	3	-	10	1	21
1931	12	7	5	-	7	5	3	-	5	18	9	23	24
1930	7	8	9	2	9	3	6	-	3	-	6	5	24
Total, 15 yrs	130	100	126	53	112	10	19	5	37	54	188	122	2/356

1/ 18 men rescued after having been barricaded for 14 hours.
2/ Includes 55 metal-mine fires and 12 outcrop fires.

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One of these fires, in a Pennsylvania mine, was caused by a trolley wire that fell on 4 cars filled with horse feed. One hundred and fifty-seven men were in the mine when the fire started; 151 escaped uninjured and without assistance, whereas the other 6 men, who were working on the main haulageway about 1,500 feet inby the fire, presumably were suffocated. The bodies were not recovered immediately, and work of sealing the mine openings was started about 17 hours after the fire started; the bodies were finally recovered several months later.

Two men lost their lives, a third man was overcome but later rescued, and a fourth man escaped unassisted after entering a Utah mine in which a fire of spontaneous origin had been burning since the previous morning.

Because of the highly combustible nature of coal, timber, explosives, and other materials usually present in coal mines, the potential hazard of fire is always present in every coal mine, even when the mine is classed as damp or wet and whether it is gassy or so-called nongassy. Some coals, ores, and other materials found or used in mines ignite spontaneously under certain conditions and create a serious hazard; however, the ignition agencies that cause most mine fires are electricity, explosives, and open lights. Although much can be done to prevent mine fires, some companies still employ methods or equipment that have caused and probably will continue to cause fires in their mines. These include the use of black powder and fuse; slipshod methods of installing, using, and maintaining electrical equipment; use of open lights; smoking; and employment of numerous other loose, unsafe, or out-of-date mining equipment, methods, and practices, one of which is to allow trolley haulage roads to become covered with fine coal dust, which makes fires from fallen trolley wires easy to start and to spread.

The following information is quoted from the News Letter of the National Safety Council, Inc., for August 1944:

> Unquestionably mine fires now constitute one of the chief means of sabotaging the effort to produce maximum quantities of mineral products essential to the prosecution of the war. This applies more particularly to coal than to non-coal mines and presumably the main reason for this is the fact that coal production in maximum quantity is still very much a 'must,' while the demand for much of the product of non-coal mines has eased materially in recent months.
>
> Since January 1, 1943, approximately 40 serious fires have occurred in the coal mines of the United States and several times that number of additional lesser fires have been handled with minimum effort or loss of production or property. The loss of life from coal-mine fires in the United States during the 18 months, January 1, 1943 - June 30, 1944, has been far greater than in any other 18 months for more than 30 years.
>
> One hundred three lives were lost in fires in coal mines in the past 18 months, 101 in fires caused by electricity and 2 in a

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fire due to spontaneous ignition. Ten of the fires of electrical origin are chargeable to the trolley haulage system, total deaths being 87. All of these fires of electrical origin occurred in highly mechanized mines. Three of the fires of electrical origin with heavy loss of life occurred on a night shift.

In the past 18 months at least 12 coal mines were sealed at the surface because of fires, 3 having men in them; 16 men were sealed in a West Virginia mine, 6 in a bituminous mine in Pennsylvania, and 66 in a mine in Ohio. This record is one of which the coal-mining industry has little reason to be proud. It is high time that coal-mining people became fire conscious.

Why has the coal-mining industry been so sadly afflicted by mine fires in the past 18 months? Unquestionably the epidemic of fires in coal mines is due to some fundamental cause or causes and it is very likely that the fires can be ascribed to more than one cause. It is a certainty that with the extreme demand for maximum production of coal, available equipment as well as manpower has been operated up to and in many cases far over capacity. As a result, much of the equipment in mines is wearing out, some of it is worn out. This is hazardous in the extreme where the equipment is of electrical type. With electrical equipment worked 2 or 3 shifts per day, 6 or even 7 days per week, little or no opportunity is available to keep it in repair. And inasmuch as spare units are out of the question and spare parts are difficult to obtain, the situation is little short of desperate so far as preventing accidents to the equipment is concerned. Added to this is the fact that man-power is scarce in the extreme. Hence, repair men are difficult to obtain and to retain.

SUMMARY

1. It is interesting to note that of the 29 major coal-mine-fire disasters with a total of 600 fatalities since 1900, only 8 (with 63 deaths) occurred since 1921 and no major coal-mine fires occurred in the United States from 1926 to 1933, inclusive. Four major fire disasters have occurred during the past 3 years; during the fiscal year 1944, a fire in a Pennsylvania mine resulted in 6 deaths; in 1943, a fire in a West Virginia mine killed 13 men; and in 1942, 10 men were killed in a fire in Colorado and 5 in a fire in Pennsylvania.

If the necessary precautions are not taken, coal-mine fires may be a great potential hazard and may jeopardize the lives of many men, not only those who are cut off from escape but also those engaged in fighting the fire. The actions of mine officials during several fires of the past few years clearly indicate lack of knowledge as to procedure in controlling such fires and an apparent indifference to the hazard resulting from them. Every mine should be provided with ample fire-fighting material placed at strategic places in the mine, and both workers and officials should be instructed in the best procedure to follow in case of fire.

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2. The decrease in frequency and severity of explosions in the United States during the past 30 years has been encouraging. The record of the fiscal year 1939 (in which there were no major explosion or fire disasters) was the best in the history of coal mining since it became a major industry; however, the increase in frequency and severity of explosions during the past 5 years has caused much concern to the agencies seeking to prevent such disasters. Most coal-mine explosions result from human failure by workers or management to take the precautions they know (or at least should know) are necessary to prevent such occurrences. Ignorance of precautionary measures is no excuse, as information on this subject has been given much publicity, particularly in the past two decades.

Although explosions of electrical origin were fewer than during each of the preceding 3 years, there still is evidence that in its demands for greater production, management and (to some extent) workers have neglected to take suitable precautions in connection with the use of electrical equipment. During the war period, with an acute shortage of skilled labor and great difficulty in obtaining equipment and replacement parts, it is doubly important for the protection of both life and property that every feasible precaution be taken.

Some of the salient points brought out by the Bureau of Mines study of explosions and fires in the United States during the fiscal year ended June 30, 1944 are:

1. Twenty-three explosions, all but two in bituminous-coal mines, were studied, as against 32 explosions in 1943 and an average of 25.8 explosions a year during the previous 15 years. This is a decrease of 28 percent compared with the previous year and a decrease of 10.8 percent compared with the average for the preceding 15 years.

2. Coal-mine explosions resulted in the loss of 94 lives during the fiscal year 1944, compared with 152 in 1943 and an average of 120 in the previous 15 years. This is a decrease of 38.1 percent from 1943 and of 21.6 percent from the average for the preceding 15 years. The anthracite mines of Pennsylvania, which employ about 75,000 men, had only 2 explosions last year and their first major explosion disaster in 6 years. The anthracite record of immunity from major explosion disasters for 6 years is decidedly creditable.

3. The five major explosions during the fiscal year 1944 caused 81 deaths, compared with the same number of major explosions and 122 deaths in 1943. Of the five major explosions in 1944, all but one occurred in mines that were wholly or partly mechanized. Three of the mines in which major explosions occurred were reported to have been rock-dusted, one was reported to have been partly rock-dusted, and one (an anthracite mine) had no rock dust. Had efficient rock-dusting to prevent propagation of explosions been in effect in the bituminous mines, the death toll undoubtedly would have been reduced greatly, and possibly one or more of the explosions would have been prevented. Failure to rock-dust a mine adequately is inexcusable, as

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rock-dusting is relatively inexpensive, and if kept up to standard, is almost certain to prevent widespread explosions.

No deaths resulted in nine of the explosions occurring during the year though some persons were burned or otherwise injured.

4. Six explosions occurred in open-light mines, compared with 11 in 1943 and an average of 8.8 in the preceding 15 years; 12 occurred in closed-light mines, compared with 17 in 1942 and an average of 15.7 in the preceding 15 years. In the fiscal year 1944, as well as in former years, some of the explosions in closed-light mines were caused by open flame, such as matches and carbide lamps, and the misuse of flame safety lamps.

Two explosions with four deaths were reported to have been caused by smoking and year-by-year explosions of this type continue to occur. Almost every year at least one explosion is caused by shot firers or officials who attempt to relight their flame safety lamps with matches; two such explosions with 14 deaths were reported during the fiscal year 1944. One explosion was caused by a match used to light a fuse. Two explosions with 26 deaths resulted when accumulations of gas were ignited by fires. Following an Alabama explosion of electrical origin that killed 18 men, 10 in a rescue party were killed by a second explosion thought to have been caused by ignition of gas by a smouldering coat set afire by the first explosion. In a West Virginia mine, 16 men were killed by an explosion while they were attempting to seal-off a mine fire. Three explosions during the year were caused by carbide lamps; such explosions and those caused by smoking are the least excusable of all, as both the workers and management know, or should know, the hazards of open flame in coal mines.

5. Eleven explosions, causing 59 deaths, were of electrical origin, compared with 19 such explosions and 66 deaths in the previous year and to an average of 11.4 explosions and 68 deaths for the previous 15 years. As pointed out, the greatly increased use of electricity with resulting necessarily greater amount of wiring, trailing cables, and other accessories, has multiplied the hazards of electrical ignitions largely because most of this equipment is operated at or near face regions where much gas and dust are given off. Under present shortage of labor and resulting lack of maintenance of equipment and difficulty in obtaining replacement of cables and repair parts, the electrical ignition hazard is more serious than it would be under normal conditions. In view of this condition, it is necessary for both the worker and the supervisor to exercise greater precautions as to ignition agencies and to see that gas and dust are not permitted to accumulate.

6. Three explosions, with 1 death, were caused by explosives during the fiscal year 1944, compared with a like number of explosions and no deaths for 1943 and an average of 3 explosions and 21 deaths annually in the preceding 15 years. There were numerous near accidents from explosives, and the use of dynamite or black blasting powder, either in granular or pellet form, in coal mines is a definite violation of established safe mining practice and it will continue to be responsible for fatalities from fires, explosions, and other causes until its use is prohibited by law or is abandoned voluntarily.

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Carelessness in the practice of using permissible explosives also is almost certain to result in disasters; in fact, carelessness in the storage and use of explosives is now and always has been in evidence in and around coal mines; and here, again, the responsibility rests jointly with workers and management. The record for the fiscal year 1944 was good even though numerous careless practices were in effect.

7. Of the explosions that occurred during the fiscal year 1944, 21 are thought to have been initiated by ignitions of gas and 2 by ignition of coal dust. In almost all of the explosions initiated by gas, it was indicated that the ventilation current had been interrupted or was inadequate or was not directed properly, and in most of these cases the use of blower fans and tubing was involved; in one or more instances it was indicated that inspections had been inadequate, and that the hazard of gas had been ignored.

Five of the explosions occurred in so-called nongassy mines. As has been the case scores of times in the past, the occurrence of these five explosions again calls attention to the fact that all coal mines are potentially gassy or may become gassy unexpectedly. The mining laws of some States are wholly inadequate with respect to the classification of mines as gassy or nongassy, and as a result many mines are operated on a nongassy basis when it is known that they are in fact gassy, in that explosive gas is known to be given off. In several instances miners have resisted the introduction of permissible electric cap lamps and oppose or violate rules to prohibit smoking in the belief that the introduction of such equipment and rules would cause the operator to relax maintenance of adequate ventilation. Elimination of all possible sources of flame is necessary to prevent ignition of gas, and resistance to such elimination on the part of miners is an erroneous approach to the real solution of the problem; the logical procedure is to insist upon adequate ventilation and simultaneously to cooperate in taking suitable measures to eliminate sources of ignition.

The two dust explosions that occurred during the year were caused by blown-out shots; many explosions have resulted from blown-out shots in the past that were the result of poor practice or the use of nonpermissible explosives or both. Considering the vast number of bad practices with explosives, the occurrence of only one or a few explosions per year is little short of miraculous.

The rapid extraction of coal by multiple-shift mechanical mining is responsible for increased liberation of gases and also contributes to the release of much dust; this requires better ventilation, more frequent inspections, and more attention to the details of the ventilation system in general. The speed with which mechanical operations are prosecuted and the tendency of crews and foremen on one shift to leave necessary repairs to be made by the following shift, or to postpone repairs or replacements until forced to take action, are not conducive to effective maintenance and certainly are highly detrimental to safety. One of the common hazards of mutliple-shift mechanical mining is the haphazard manner in which cable splices are made and maintained in many mines; slipshod trailing cables also induce numerous

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hazards, such as contact electrocution, the release of stray currents likely to precipitate premature blasting or misfires, and the possibility of arcs or sparks that are likely to ignite gas or dust.

8. The frequency of explosions during the past year (23) declined markedly as compared with the previous year (32). The average number of deaths per explosion last year was 4.1, compared with 4.7 in 1943 and 4.7 during the preceding 15 years.

9. The 23 explosions and 94 deaths during the fiscal year 1944 occurred in 8 States and Alaska, and 18 other coal-producing States had no known explosions. The 6-year immunity from major explosion or fire disaster in the anthracite region was broken; the record was one of which the anthracite region had reason to be proud, and it is hoped that there will be no major disasters in the anthracite region for another decade at least.

10. The facts brought out by a study of the explosions that occurred during the past year stress the importance of allaying coal dust at its source. The five major explosions during the year were responsible for 86 percent of the fatalities resulting from explosions, and all were extended by coal dust. This would indicate that adequate precautions are not being taken to prevent the spread of explosions. Mechanical mining of coal produces much more fine coal dust than hand-loading methods, hence the need for allaying the dust at its source is greater than ever before in the history of the industry. Fine coal dust is an explosion and health hazard, and every feasible precaution should be taken to suppress it at its source. Much is being done in this connection, but the good start made by a few companies should be extended to many others in fact, to all coal mines.

11. Rock dust was reported to have been used in only 9 of the 23 mines in which explosions occurred during the past year; in only a few of these so-called rock-dusted mines had a sincere effort been made to do a good job. The severity of the major explosions during the past several years is mute evidence of the inadequacy of rock-dusting practiced in the coal mines of the United States. This is inexcusable, as rock dusting costs only a very few cents per ton of coal.

12. During the fiscal year 1944, 32 coal-mine fires with 8 deaths were reported, compared with 27 fires and 15 deaths in 1943 and to an average of 23 fires and 8.1 deaths annually for the preceding 14 years.

13. Of the 32 fires that occurred during the year, 12 were of electrical origin, 3 were caused by explosives, and 17 were of miscellaneous or unknown origin. No fires were reported as having occurred in underground metal mines, but fires occurred in surface plants at 15 metal mines.

14. The frequency and severity of mine fires have increased at an alarming rate during the past 3 years. Most of the fires in coal mines have been of electrical origin, many of them caused by the trolley system; this emphasizes the need of careful installation and maintenance of underground electrical circuits and equipment. In addition to causing heavy loss of life, fires

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usually cause serious property damage and almost invariably require considerable ultrahazardous effort in extinguishment or control. The potential hazard of fire in any mine is always serious, especially in coal mines, because a fire can precipitate an explosion; two major explosions were brought about by mine fires during the past year. The definite fire hazard that exists in virtually all mines should be recognized, and every feasible precaution should be taken to prevent them. Also, plans should be placed in effect to handle fires quickly and safely if or when they occur, and underground officials and employees should be instructed in procedure to follow in case of fire and especially in event they are trapped behind a mine fire.

CONCLUSIONS

This circular was compiled in essentially the same manner as were those of previous years (see Information Circulars 6178, 6419, 6540, 6680, 6819, 6870, 6761, 6927, 6986, 7048, 7092, 7136, 7208, and 7274) and embodies only facts revealed by studies of field employees of the Health and Safety Branch of the Bureau of Mines. The Bureau of Mines attempts to obtain information concerning every explosion and most of the fires in mines of the United States. Although some of the less destructive mine explosions and fires may not have been brought to the Bureau's attention early enough to permit investigation, it rarely fails to obtain fairly complete details of mine explosions or fires in which more than one life has been lost or in which considerable property has been damaged; therefore, the data in these publications are relatively complete.

A study of available data on mine explosions in the United States during the past 16 years reveals that there was an encouraging reduction in the frequency and severity of such disasters until 1940; however, the record was not so encouraging during the next 4 years, though that for the fiscal year 1944 was the best since 1939. Explosions in mines in the United States have resulted in an average of 119 fatalities annually during the past 16 years, compared with 94 fatalities in 1944, 152 in 1943, 152 in 1942, 163 in 1941, and 206 in 1940.

The undue prevalence of major coal-mine explosions and fires during the past 5 years indicates a lack of effective precautions to prevent such disasters. Four of the 5 major explosions in 1944 occurred in mechanized mines. In three of the major explosions in which 53 men were killed, electricity is believed to have been the initiating cause, and the other, in which 12 were killed, was caused by an official attempting to relight a flame safety lamp with a match. In most of the mines in which explosions occurred, numerous unsafe practices were followed; some evidently were the result of a lack of respect (possibly a lack of knowledge) for the hazard of gas and others were due to neglect of necessary yet readily feasible safety measures, such as the elimination of the sources of ignition of gas or dust.

The more rapid extraction of coal with mechanical methods calls for much greater ventilating efficiency, and unless ventilation is maintained so that enough fresh air reaches all working faces to dilute the gases, explosions

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are certain to continue to occur. In nearly every instance of explosions initiated by ignitions of gas, some deficiency in ventilation has come to light. Consequently, ventilation must be made more effective, and greater vigilance must be maintained in the detection of gas and in eliminating or neutralizing dust, as well as in the elimination of ignition agencies. Many explosions result directly or indirectly from carelessness or infraction of rules by employees; therefore, the prevention of explosions is the responsibility not only of management but of the workers as well. Irrespective of responsibility, the seriousness of the situation brought about by the very bad coal-mine-explosion record of the past 5 years cannot be questioned. The demand for greater production and the existence of strenuous working conditions, owing to the war, necessitate greater vigilance by the workers, the management, and other agencies interested in mine safety if the number and severity of coal-mine disasters is to be reduced to a reasonably low minimum. In the appendix are a number of suggestions as to suitable procedures for the prevention of conditions in mines that are likely to contribute to the occurrences of mine fires or explosions. These suggestions are not fanciful, nor are they impractical. Essentially every one is in effect in one or more mines in the United States, though probably no one mine follows all of them.

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APPENDIX

EXPLOSION AND FIRE-PROTECTION MEASURES FOR COAL MINES

Surface Fire Protection

1. All buildings within a radius of 100 feet of mine openings should be of fireproof or fire-resistant construction. If existing buildings within 100 feet of the openings are not so constructed, fire doors should be erected at effective points (in shafts, drifts, or slopes) where smoke or fire from outside sources may endanger men working underground. These doors should be tested at least every 3 months to assure effective operation.

2. Adequate fire protection should be provided. Fire-fighting equipment should be readily accessible and the location of such equipment plainly marked.

3. A fire-fighting organization should be maintained and, if feasible, fire drills should be held at least twice a year.

Explosives and Blasting

1. All explosives used in underground coal mines should be of permissible type. Permissible explosives should be used as follows:

   a. Consist of not more than 3 pounds in any one shot.
   b. Fired only with electric detonators of proper strength.
   c. Fired with permissible shot-firing units.
   d. Not be fired on the solid unless it is not feasible to cut the coal.
   e. Stemmed with incombustible material.

2. Shots should be charged and fired by certified shot firers, other certified officials, or authorized persons known to be competent.

3. If physically possible, the coal should be cut; if cut or sheared, boreholes should not be drilled until after the cut or shear has been made.

4. Boreholes should be drilled at least 6 inches shallower than the depth of the cut or shear.

5. Explosives should be suitably stemmed with clay or other incombustible material, preferably to the collar of the hole; in no instance should the stemming be less than 2 feet in length, unless the hole is stemmed to the collar.

6. Only permissible shot-firing units should be used (if they can be procured) unless blasting is being done from the surface when all men are out of the mine.

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7. Examination for gas should be made before and after firing a shot or shots in a gassy mine.

8. A shot should not be fired when more than 1 percent of methane is known to be present.

9. Adobe (mudcap) or other open, unconfined shots should not be fired in any bituminous or lignite mine.

Ventilation

1. Main fans should be:

   a. Installed to permit reversal of air flow.
   b. Operated continuously, except when the mine is shut down for an extended period.
   c. Provided with automatic device to give alarm, when the fan slows or stops, unless the fan is constantly attended.

2. If the main fan of a gassy mine fails or stops for 5 minutes or more, the men should be withdrawn from the mine immediately. After the fan has started, the mine should be examined thoroughly for gas, and any gas found should be removed before the men reenter the mine. The same procedure should be followed in a section of a gassy mine if it is dependent upon a booster fan.

3. If stoppage of a main fan of a gassy mine is more than momentary, mine electric power should be cut off the face sections; and if stoppage is for 5 minutes or more, power should be cut off from the entire mine. A thorough gas examination should be made before power is restored.

4. A booster fan should be used only for ventilating a distant extension of a mine which it is impracticable to ventilate by improvement of airways and if the construction of a new ventilation opening is not feasible. If installed for such reason, the fan motor should be of enclosed type, the surroundings of the fan fireproofed, and the fan so installed and so located with respect to workings as to reduce the possibility of recirculation of air.

5. Auxiliary fans or blowers with tubing should not be used in coal mines except to ventilate faces of rock tunnels being driven between two coal beds or through faults and wants; if used in rock tunnels, they should be powered with permissible driving units and so placed that there is no recirculation of air.

6. A mine should be classed as gassy when 0.10 percent or more methane or other combustible gas can be found in any open workings by systematic search, or if the mine records establish the fact that methane has been found or ignited, provided that any classification of a mine as gassy by analyses of air samples should be based on two or more samples, each containing 0.10 percent or more of methane.

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7. The main intake and main return air currents in mines should be in separate shafts, slopes, or drifts.

8. If flammable gas can be detected in the air of a working place with a flame safety lamp, or if such air contains more than 1 percent of flammable gas as determined by an electric methane detector or by chemical analysis, ventilation should be improved immediately. If air in the working place contains more than 2 percent flammable gas (slightly less than 1/2-inch cap on a testing or low flame of a flame safety lamp), the workers should be withdrawn until the ventilation is improved. By "air of a working place" is meant air not nearer than 1 foot from the face. Air should be tested for gas at such points as conditions may warrant.

9. If the air immediately returning from a split that ventilates any group of active workings contains more than one-half percent of flammable gas, as determined by chemical analyses in duplicate or by other recognized means of accurate detection, ventilation should be improved immediately if at all possible. If this air contains more than 1-1/2 percent of flammable gas, the workers should be withdrawn until ventilation has been improved.

10. The quantity of air reaching the last open crosscut on any pair of working entries or the maximum inby point of a split should be at least 6,000 cubic feet a minute.

11. Each working place should be ventilated by a perceptible air current of sufficient quantity to dilute and carry away flammable or harmful gases that may be present.

12. All entries, rooms, panels, or sections that cannot be kept well-ventilated throughout and regularly inspected or that are not being used for coursing the air, travel, haulage, or the extraction of coal should be sealed by substantial fireproof stoppings.

13. Crosscuts should be made at intervals capable of assuring adequate ventilation at faces.

14. Stoppings between intake and return of all main haulageways should be as nearly airtight as possible and constructed of substantial incombustible material, except that one temporary stopping of wood or brattice cloth may be erected between the last permanent stopping and the last crosscut. However, in heavy or caving ground, timber laid longitudinally, skin to skin, may be used.

15. On branch haulageways, stoppings should be as nearly airtight as possible and constructed of incombustible or fire-resistant material with the exception stated in the preceding recommendation.

16. Room crosscuts should be closed where necessary to obtain a perceptible movement of air at the face.

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17. Not more than one crosscut should be left open between the faces of entries and the first outby temporary or permanent stopping.

18. Where doors are used in connection with coursing the air in any one split or if used in lieu of a split ventilation system they should be:

a. Installed in pairs to form air locks, or, where this is not feasible, tight check curtains, well-maintained, should be hung in connection with single doors. Air locks should be ventilated sufficiently to insure against the accumulation of gas within the enclosed region.
b. Self-closing.
c. Provided with a supply of rock dust on each side for fire emergency use if doors are of wood.
d. Hung so that they swing to the clearance side.
e. Hung so as to open against the ventilating current.

19. Line brattice should be:

a. Used to conduct the air from the last open crosscut to working faces when necessary to remove gases, explosives fumes, smoke, and dust.
b. Constructed with boards at top and bottom or otherwise secured to provide face ventilation.
c. Be of mildew- and fire-resisting material.

20. Working places should not be ventilated by an air current that has passed through abandoned workings or pillar lines. (It is hazardous to work places ventilated by air currents from partly caved more or less inaccessible areas.)

21. At least two permissible flame safety lamps should be kept in safe working condition at every coal mine, and at least two persons should be kept well-informed as to the safe maintenance and use of flame safety lamps.

22. All coal mines classed as nongassy should be inspected carefully for methane at least weekly.

23. Only permissible methane detectors and air sampling and analysis should be used for determining methane. (Permissible flame safety lamps are considered a type of permissible methane detector.)

24. All men required to use methane detectors should be instructed thoroughly in their use and limitations.

25. Enough fire bosses should be employed in gassy mines; they should:

a. Begin examination of the mine not more than 3 hours before each shift enters it; however, in multiple-shift operations, such examination may be made within 3 hours of the next shift by qualified officials of the shift on duty.

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b. Examine every working place, all places adjacent to live workings, every roadway and travelway, every unfenced road to abandoned workings, and all accessible falls in the mine for explosive gas and other hazards.
c. Leave their initials and the date at or near the face of each place examined.
d. Place a danger sign across the entrance to every place where a dangerous condition is found. The danger sign should be removed only by a certified official after the danger has been removed.
e. Report to a proper official on the surface or at designated underground stations any dangers found before the men enter the mine or pass such designated stations.
f. Record in ink the results of their inspection in a book kept on the surface for that purpose. Similar records also should be kept at designated underground stations.

26. Accumulations of gas should be removed under the direct supervision of a foreman or other competent official, and no men should be permitted to work, nor should electric equipment be operated, on the return of the split while gas is being removed.

Control of Coal Dust and Rock Dusting

1. Coal dust should not be permitted to accumulate on roadways, along conveyor lines, and on gob, roof, rib, or timbers.

2. Machine cuttings from coal beds (unless the dust therein contains more than 65 percent incombustible) should be loaded and hauled out of the mine if at all practicable. If removal from mine is not practicable, cuttings should be placed back from the face and covered with a layer of one-half inch or more of rock dust.

3. Mine cars should be maintained as nearly dust-tight as possible.

4. To allay coal dust, water or wetting solutions should be used on loading machines, on the cutter bars of mining machines, and at other evident sources of dust.

5. All bituminous-coal mines (lignite mines excepted) should be kept thoroughly rock-dusted in all open, unsealed places to within at least 40 feet of the face. If the top, floor, and sides of the mine (or any part thereof) are wet, rock-dusting is not required in such mine or part thereof; however, if there is any indication that the mine, or any part thereof, is becoming dry, the mine or portion of the mine so affected should be rock-dusted.

6. Where rock dust is applied, it should be distributed upon the top, floor, and sides of all open, unsealed places and be maintained in such quantity that the incombustible content will not be less than 65 percent.

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7. When methane is present in the ventilating current, the 65 percent minimum percentage of incombustible should be increased 1 percent for each 0.1 percent methane.

8. Sampling should be done frequently enough to determine whether additional rock dust is required.

9. A record should be kept of the places of sampling, the results of the tests made, and the amount of rock dust applied monthly as well as annually.

Electricity

1. Electrically driven equipment operated inby the first open crosscut between entries or rooms or in air that has ventilated one or more working places in mines classed as gassy should be permissible. It is recognized that under war conditions it may be difficult, if not impossible, to obtain permissible equipment, and that nonpermissible equipment is now and will continue to be used in gassy mines; where nonpermissible electrical equipment is used, all possible precautions should be taken.

2. If nonpermissible electric equipment is used in face regions (inby first open crosscut or air that has ventilated one or more working places) of gassy mines, it should be operated only under the following conditions:

a. Each working place should be examined carefully for methane by a certified official or other competent person immediately before the equipment is taken into or operated in a working place.
b. The general air of the place should not contain more than one-half of 1 percent of methane as determined by analysis or other recognized means of detecting methane. (By "air of place" is meant air not nearer than 1 foot from the face. Any indication of methane on a flame safety lamp should be regarded as more than one-half of 1 percent of methane.)
c. If more than 1 percent methane can be found in holes in the roof of any working place by analysis or by methane detector (flame safety lamp or electric detector) the equipment should not be taken into or operated in the working place until the pocket of gas has been removed by additional ventilation.
d. When electrical equipment is used in face regions, tests for methane should be made at least every 30 minutes by a certified official or other competent person.

3. Electrically driven permissible equipment should not be taken into or operated in any place if methane amounting to more than 1 percent can be found (by analysis or other recognized means of detecting methane) in the general air of the place.

4. Electrically driven permissible equipment operating in face regions in a gassy mine should be stopped at least every 30 minutes and the place carefully examined for methane by a certified official or other competent person.

5. Permissible equipment should be maintained in a good state of repair and in permissible condition.

6. Underground electric stations for permanent installations of pumps,

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compressors, motor-generator and other conversion equipment, storage-battery-charging stations, and transformers should be located in well-ventilated, fireproof rooms.

7. Portable pumps and other portable electrically driven equipment should be so located and installed as to constitute the minimum possible fire or man-contact hazard. They should be used only in well-ventilated places.

8. Portable transformer stations should be in fireproof housing either fully enclosed or fitted with doors that close automatically in case of fire. They should be located only in well-ventilated places.

9. Battery-charging stations should be well ventilated. If practicable such stations should be in fireproof rooms and the air ventilating them conducted directly to return airways.

10. Wires or other substitutes that do not provide adequate protection should not be used in place of proper fuses.

11. Fire extinguishers approved for electrical fires should be available at all electric installations. If such extinguishers cannot be obtained, rock dust should be available.

12. Clean, dry sand or rock dust and, if available, fire extinguishers suitable from both a toxic and shock standpoint should be provided and placed outside of underground electric stations so as to be out of the smoke in case of fire in the station.

13. Trolley and bare power wires should be:

a. Securely supported on insulated hangers not more than 30 feet apart.
b. Sectionalized by proper electric switches at intervals not to exceed 1,500 feet; electric switches should also be installed in all branch lines near their beginning.
c. Provided with sectionalizing switches at points where loaded mine cars are stored on idle days.

14. Power wires other than trolley wires should be well-insulated where they pass through doors or stoppings.

15. Trolley or feed wires should not extend beyond the last open crosscut and should be kept at least 150 feet from the end of pillars, workings, or an open, partly caved, poorly ventilated places.

16. If feasible, power should be cut off from idle sections of a mine and from the entire mine on idle days. This statement is not, however, intended to bar the use of lines, properly protected by fuses, for the operation of such units as pumps if all passageways and adjoining areas through which live circuits pass (including surroundings of units) are examined with a flame safety lamp and found free of gas.

17. Officials, haulage crews, electricians, and others connected with electrical maintenance should be familiar with the location of cut-out switches.

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18. Circuit breakers should be provided to protect all power circuits. If they are automatic, they should be set so that the circuits cannot be overloaded; if they are hand-set, the handles should not be tied in place.

19. In gassy mines, permissible junction or distribution boxes should be used where feasible in making power connections at working faces.

20. Cables for portable or semiportable underground electric equipment should be provided with suitable taps equipped with fuses, unless properly connected to permissible junction or distribution boxes.

21. Temporary cable splices should be made in a workmanlike manner, mechanically strong, and well-insulated. Preferably, when a cable is defective, a stand-by cable should be used and the defective cable sent to the shop for permanent splicing and, if practicable, vulcanizing.

22. To prevent excessive heating, the trailing cables of equipment used in conveyor mining should be suspended in long loops rather than tightly coiled.

Fire Protection Underground

1. Underground storage places for lubricating oil and grease should be of fireproof construction.

2. Lubricating oil and grease kept in face regions or other working locations should be in portable, closed, metal containers.

3. Inside structures (substations, shanties, stables, pump rooms), including doors, should be of fireproof construction.

4. Hay or straw should be stored in a fireproof structure apart from the stable.

5. Welding and cutting (with electricity or flame) in gassy mines in face regions and on returns should be done under the immediate supervision of a certified official. No welding or cutting should be done if more than 0.50 percent methane is present. In all welding and cutting operations, special precautions should be taken against starting fires.

Miscellaneous Hazards

1. When a limit of 200 feet is reached from abandoned workings that cannot be inspected or workings filled with water not exceeding a 150-foot head, or gas, boreholes should be kept at least 20 feet ahead of the face; similarly 45° angle holes at least 25 feet deep and not more than 8 feet apart should be made in each rib. If the head of water exceeds 150 feet, the depth of the boreholes should be increased 1 foot for each additional 10-foot head of water.

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2. In regard to mine openings:

a. Every underground mine should have at least two separate outlets to the surface.
b. Each bed of coal and each level or entry therein should have at least two travelable openings in connection with (directly or indirectly) both main outlets to the surface.

3. Designated escapeways should be readily accessible from every section of the mine and should be kept in a safe condition, reasonably free from steam, dangerous gases, standing water, ice, and other obstructions.

4. Direction signs should be posted conspicuously to indicate manways and designated escapeways.

5. A check-in-and-out system should be adopted that will provide positive identification, upon the person, of every individual underground. An accurate record of the men in the mine should be kept in a place that will not be affected in the event of an explosion.

6. Oil and gas wells penetrating strata below beds of coal should be protected by a pillar of coal extending at least 50 feet from the well in every direction.

7. A 50-foot barrier pillar, or larger if deemed necessary, should be left when workings adjoin old workings suspected of containing bodies of dangerous gas. If the danger is from water, the barrier pillar should be of a width determined by qualified engineers and approved by the proper State agency.

8. Smoking should not be permitted in any mine.

9. Only permissible portable electric lamps, preferably cap lamps, should be carried by all persons for illumination in a mine.

GENERAL SAFETY CONDITION

Supervision

1. Idle or abandoned sections of a mine should be inspected for gas and other dangerous conditions by a foreman or fireboss immediately before other employees are permitted to enter such sections.

2. Aircourses and accessible pillar falls should be traveled at least once each week by a certified mine official, who should leave his initials and the dates; if any part or parts of the aircourse are in such condition that it cannot be traveled, the defective condition or conditions should be remedied promptly. Written reports should be made as to conditions found on such inspections.

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3. All entrances to dangerous places should be fenced off, and suitable danger signs should be provided at safe distances from the existing hazard.

4. Each working place should be inspected for safety by a certified official at least twice each working shift and at such more frequent periods as may be necessary and practicable.

First Aid and Mine Rescue

1. At least 10 sets of oxygen breathing apparatus and at least 6 gas masks and necessary accessories should be available in each mining district for use in case of mine fire or explosion. This equipment should be available at centrally located rescue stations owned by the State or operators in the district, or be owned by individual companies. This equipment should be readily available at all times.

2. When training facilities are available, at least 12 men should be trained in mine rescue work at mines having more than 100 employees; mines having 100 employees or less should have a proportionately smaller number trained, but not fewer than 6.

3. Mine officials should take an advanced mine rescue course when such course is available.

FIRE-PREVENTION MEASURES FOR METAL MINES

General

1. Adequate fire protection should be provided.

2. Fire hydrants should be standard and interchangeable with local fire-department hose equipment. Adapters should be provided if necessary.

3. Fire hydrants should be located at a safe distance from all buildings so that a fire could not render them useless. This is not intended to prevent the installation of additional fire hydrants at or in the various buildings.

4. Fire lines should be tested at frequent intervals, especially during the winter months, to insure their being in working condition. A record should be kept showing the date of each test and the conditions found by the inspector.

5. Fire-fighting organizations should be maintained on each shift, and frequent fire drills should be held.

6. "Good housekeeping" is essential to good fire protection and should be enforced at all times.

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Storerooms and Warehouses

1. Gasoline should be stored in underground tanks when practicable.

Surface Plant

1. Flammable materials should not be permitted to accumulate in or around any building.

2. Carbon tetrachloride or CO_2-type fire extinguishers should be provided for electrical fires and should be placed in easily accessible places.

3. A careful fire inspection should be made after using oxyacetylene, oxyhydrogen, or electric-welding equipment.

Surface Buildings

1. Only buildings of fireproof construction should be permitted over or connected to mine shafts, tunnels, or adits.

2. All buildings within a radius of 100 feet from any mine opening should be of fireproof or fire-resistant construction.

3. Fire doors should be erected at mine openings or effective points where smoke or fire from outside sources may endanger men working underground.

4. Open lights should not be permitted near open carbide containers. The use of carbide dispensers is recommended both as a fire-preventive and a safety measure. Preferably, electric cap lamps should be used rather than any type of open light.

Shafts

1. Headframes should be protected from accumulations of combustible material.

2. Shaft stations should be adequately protected against fire hazards. Some mines have a fire-hose connection (with suitable pressure reducing valves) from the pump column that can be used in case of fire.

3. Flammable material should not be allowed to accumulate at or near a shaft station.

4. Oils, greases, gasoline, and other flammable liquids should not be stored at a shaft station.

5. Not more than one barrel of lubricating oil should be stored on any one level underground.

6. Hay, straw, or flammable feed material taken underground should be in compressed bales, covered by tarpaulin, in a container, or in a closed car

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It should be delivered promptly to the underground stable and stored in a locked fireproof compartment. The amount of hay stored underground at any time should not exceed the amount normally consumed in 48 hours, unless this amount is less than one bale.

7. All timbered shaft stations on levels where work has been done during the shift should be inspected for fire at the close of the shift and a record kept of the inspection.

8. Fires for heating should not be permitted underground. Open-flame torches, lighted acetylene lamps and candles should not be left unattended; preferably they should not be used.

Tunnels and Adits

1. Snow sheds, buildings, or other structures covering the approaches and portals of tunnels or adits should have adequate fire protection and should be of fireproof construction if connected to the mine opening.

2. Flammable materials and liquids should not be stored in shelters, sheds, or covered approaches of tunnels or adits.

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